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Modified Sacchurum Officinarum (Sugarcane Bagasse [Sb]) Activated Powder Used as a Natural Adsorbent for the Removal of Cadmium (Cd) From Simulated Wastewater (Aqueous Solution)

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Abstract: Cadmium is one of the heavy metals that have been classified by the World Health Organization (WHO) to be of serious health concern (Hundal, 1998). The "itai-itai" disease which is of cadmium toxicity in humans, kidney dysfunction and hepatic damage other health implications of cadmium (Klaassen, 2001).[3] Cadmium is used in many industries such as the electroplating industry, pesticides, dyes, pigments, plastics nickel-cadmium batteries, and textile operation (Yavuz et al. 2007). The permissible limit for cadmium as described by the World Health Organization (WHO) is 0.01 mg/L (Peterlene et al. 1999). There are several ways to remove cadmium like solvent extraction, precipitation, ion exchange, and adsorption etc. This study investigates the modified form of sacchurum officinarum (sugarcane bagasse [SB]) activated powder used as low cost natural adsorbent for removing cadmium from an aqueous solution. Adsorption studies were carried out to determine the influence of contact time, adsorbent dosage, effect of stirring rate and pH on removal efficiency.
Keywords: Adsorption, Cadmium, waste water, low-cost adsorbent, eco-friendly.

I. INTRODUCTION

Heavy metals are the natural components of the Earth's crust, they cannot be destroyed and they enter our bodies from various sources like food, drinking water and air etc. Particularly, cadmium is one of the very toxic metal ions as it is a non-essential and non-biodegradable metal ion. Accordingly, it is accumulated in the blood causing a variety of symptoms such as kidney damage, high blood pressure, and destruction of red blood cells. Cadmium is used in various industries such as the electroplating industry, plastics, pesticides, dyes, nickel-cadmium batteries (Yavuz et al. 2007). The permissible limit for cadmium as described by the World Health Organization (WHO) is 0.01 mg/L (Peterlene et al. 1999). Therefore, the removal of cadmium from wastewater is essential from an environmental point of view. Various physico-chemical methods have been developed to remove cadmium from aqueous solutions including: filtration, reverse osmosis, solvent extraction, ion exchange, membrane separation, and adsorption by activated carbon etc. Among all, the adsorption is an easy and cheap process for removal of metal ions from the polluted water, because it is a cheap, simple, economic and suitable operation method and it is significant to exploit simple, novel and high efficient adsorbents for this approach (Deng et al. 2010; Mall et al. 1996).All over the world cadmium contaminated waste water and effluents are being generated either directly due to Cd production or through secondary sources. A major past disaster 'Itai-Itai' due to contamination of cadmium in Jintsu river of Japan is well known.[3] Adsorption is a highly effective and economical technique for the removal of heavy metals from polluted water. Therefore, ecofriendly and cost effective new technologies are required for the removal of heavy metals like cadmium from waste water stream by appropriate treatment before releasing into water bodies. A low cost adsorbent is the one which needs a little effort before use. Natural materials of certain waste from industrial or agricultural operation are one of the resources for low cost adsorbents. Generally, these materials are cheap and easily available in large quantities.

Experiments were conducted in removal of cadmium from aqueous solutions using sacchurum officinarum (sugarcane bagasse [SB]) activated powder which is available in all areas of India. Sugarcane bagasse it is having least economic value and hence it is considered as an agricultural waste material. The aim of the present study was to examine the feasibility of using low cost natural absorbents such as sacchurum officinarum (sugarcane bagasse [SB in cadmium removal using adsorption technique. Adsorption characterization was done by using spectrophotometer. The effect of adsorbent dosage, shaking speed, contact time, pH, initial and final cadmium concentration were determined.

II. EFFECTS OF CADMIUM (CD)

The ill effects of cadmium on human being, animals and plants vary from time to time depending on the concentration and individual fitness. The "itai-itai" disease which is a manifestation of cadmium toxicity in humans, kidney dysfunction, hepatic damage and hypertension are also other health implications of cadmium (Klaassen, 2001). It also causes cancer and genetic changes (Hill, 1984).

Water Quality Standards

Standards	Drinking water (mg/L)	Wastewater (mg/L)
WHO	0.003	0.1
ISI	0.01	0.3
EPA	0.05	0.3
CWQG	0.001	0.05

A. Practical experiences of the related work

Mohammad Mehdi Mehrabani Ardekani, Roshanak Rezaei Kalantary, Sahand Jorfi, Mohammad Nurisepehr (2013) compared the efficiency of Bagasse, Modified Bagasse and Chitosan for fluoride removal from water by adsorption. The pH value of 7, contact time of 60 min and adsorbent dose of 2 g/L were determined as optimum conditions for all three adsorbents. Chitozan and bagasse did not show good capability for fluoride removal, but modified bagasse showed more than 90% removal at optimized conditions, including the pH value of 7, contact time of 60 min and adsorbent dosage of 2 g/L. Both Langmuir and Freundlich isotherms show good correlation for description of results, but the Langmuir model with the correlation value of 0/99 is superior.

Younesi et al. (2006) studied cementation of cadmium ions by zinc powder in a batch reactor at low and high concentrations at pH 5.2–5.4 and it was shown that the reaction was first-order. XRD and SEM analysis confirmed that the deposited layer was metallic with no evidence of basic zinc sulphate or re-dissolution of cadmium. The experiments demonstrated that at initial cadmium concentrations of > 1000 mg/L, the ash diffusion control model prevailed, while at concentrations < 500 mg/L, the data had good agreement with the film diffusion model. For concentrations between 500 mg/L and 1000 mg/L, a combination of ash diffusion and film diffusion models controlled the reaction rate. Statistical data analysis was performed and different reaction rate constants were estimated from the equations for high and low initial cadmium concentrations.

Gould et al.'s report (1986) revealed that cadmium could be removed by cementation with magnesium. They reported that the order of kinetics depended on the initial concentration. It was half order up to 25 mm (migration control mechanism) and first order (diffusion control) beyond 25 mm.

Ku et al. (2002) reported that cadmium could be removed from solutions by cementation with zinc powder. The optimum pH found was 4-5. The reaction rate was approximately first order with respect to both the amount of zinc and the concentration of cadmium ion. Among the surfactants used in this study, only the presence of sodium dodecyl sulfonate, an anionic surfactant, noticeably enhanced the cementation rate of cadmium by zinc powder. The presence of ethylene-di amine tetra acetic acid (EDTA) in aqueous solutions inhibited the removal of cadmium by zinc due to the possible formation of Cd-EDTA chelates, which possess higher redox potential than that of free cadmium ions.

Xue et al. (2009) were interested in finding the suitability of basic oxygen furnace (BOF) slag to remove cadmium, lead, copper and zinc from waste waters. The BOF slag used during the studies contained heterogeneous oxide materials which are compounded by some main oxides such as CaO, Fe2O3, SiO2, Al2O3, and MgO. The value of pH50 (the pH at which 50% adsorption occurs) was found to follow the sequence Zn(II) > Cu(II) > Pb(II) > Cd(II) in single-element systems, but Pb(II) > Cu(II) > Zn(II) > Cd(II) in the multi-element system. The adsorption and potentiometric titrations data for various slag– metal systems were modeled using an extended constant-capacitance surface complexation model that assumed an ion-exchange process below pH 6.5 and the formation of inner-sphere surface complexes at higher pH. Inner-sphere complexation was more dominant for the Cu(II), Pb(II) and Zn(II) systems.

III. EXPERIMENTAL WORK MATERIALS AND METHODS

A. Preparation of Adsorbent

1) Adsorbent of sacchurum officinarum (sugarcane bagasse [SB]): Sugar cane bagasse is low cost and easily available from all local juice corners. Firstly we cut into small pieces and grinded then washed several time with distilled water and dried for 3-4 hours in hot air oven or 3-4 days sun dried then treated with 0.1N HCl and again wash also treated with sodium carbonate. After that it was sieved to pass through a 2 mm stainless steel endecott sieve and a portion of this was stored in clean polyethylene containers (labeled as unmodified adsorbent) prior to analysis . For the modification of the adsorbent, about 500 g of the washed adsorbent was mixed with 600 ml of 0.1 mol dm^{-3} NaOH. The mixture was heated at 120^oC for 30 min with occasional stirring. To observe the cadmium removal, we use spectrophotometer, first we calibrate the spectrophotometer by double distilled water to set absorbance zero, and then set 100 absorbance by the spand reagent solution.

Modified Sacchurum Officinarum (Sugarcane Bagasse [SB])

2) Reagents: Chemicals such as HCl, HNO3, ethylene diamine tetra acetic acid (EDTA), and NaOH were supplied by Merck, and de-ionized water was used. The standard solutions of Cd (II) ions were prepared by dissolving reagent grade Cd (NO3)2·4H2O with distilled water to the desired concentrations. In batch experiments, the optimum pH of the solution was adjusted to 5.0 by addition of 0.1 M NaOH or 0.1 M HCl solution.[3]

3) Batch studies: All experiments were carried out at room temperature i.e. 25^oC. Batch test was carried out by shaking cadmium solutions with solid at constant agitation speed 100 rpm and after separation by centrifuge, the solution of Cd2+ was analyzed by using atomic absorption spectrophotometer. The percent removal of Cd2+ was calculated as follow:

% removal of $Cd2^+ = [(C_o - C_e) / C_o] \times 100$

Where: C_o and C_e are the initial and final Cd2+ concentrations (ppm) respectively.

IV. RESULTS AND DISCUSSION

A. Effect of contact time

The effect of contact time for the efficient removal of metal ion was studied in this process. The Cd2+ showed a steady rate increase of sorption during the sorbent contact time process and the rate of removal became almost insignificant due to a quick exhaustion of the adsorption sites. The rate of metal removal is higher in the beginning due to a larger surface area of the adsorbent being available for the adsorption of the metal[5]. In this study 35% of Cd2+ removal was achieved at 75 minutes. Further, no significant changes were observed in the removal of Cd2+ from solution after 2 hours of equilibration.

Dose(g/100ml)	Time (in min.)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.5	10	2	2.0	0.0	00
0.5	15	2	1.9	0.1	5
0.5	30	2	1.7	0.3	15
0.5	60	2	1.5	0.5	25
0.5	75	2	1.3	0.7	35
0.5	90	2	1.3	0.7	35

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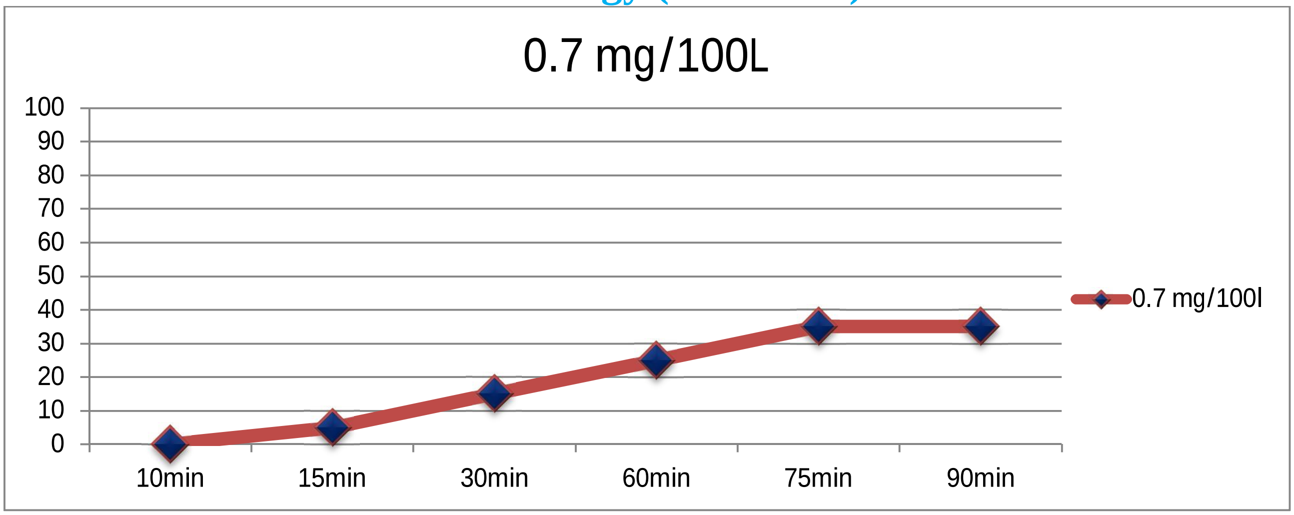
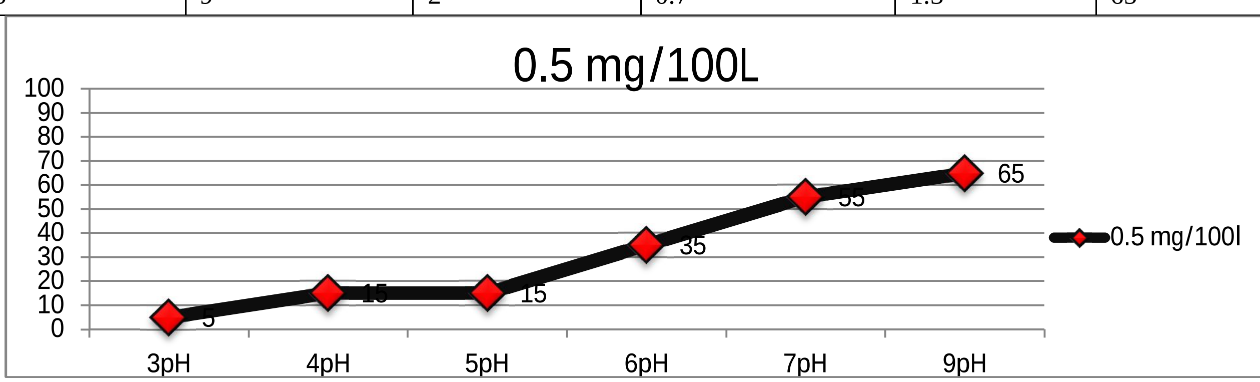


% Cadmium removal

B. Effect of pH

The effect of the pH on the removal of cadmium was studied by varying the pH from pH 3 to 9. The results are presented, where it can be seen that maximum removal of about 65% is found at a dose of 5 g/L at 9 pH of sample and thereafter the percent removal became more or less constant.

Dose(g/100ml)	pH	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.5	3	2	1.9	0.1	5
0.5	4	2	1.7	0.3	15
0.5	5	2	1.7	0.3	15
0.5	6	2	1.3	0.7	35
0.5	7	2	0.9	1.1	55
0.5	9	2	0.7	1.3	65



% Cadmium removal

C. Effect of Stirring rate

The effect of the stirring rate on the removal of cadmium was studied by varying the stirring rate from 30 to 150 rpm. The results are presented, where it can be seen that maximum removal of about 55% is found at a stirring rate of 150 rpm and thereafter the percent removal became more or less constant.

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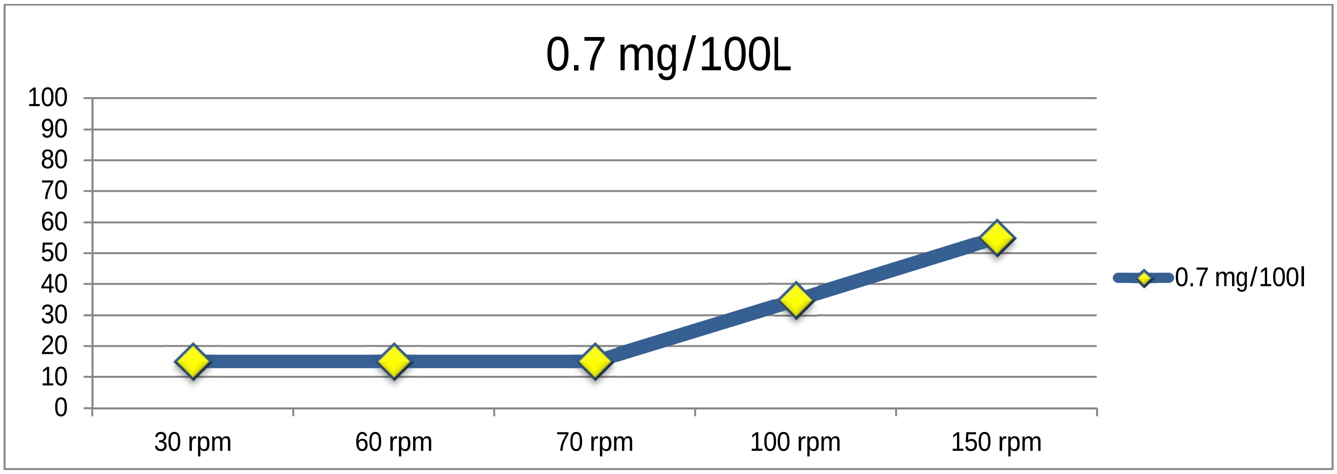
Dose(g/100ml)	Stirring rate (rpm)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.7	30	2	1.7	0.3	15
0.7	60	2	1.7	0.3	15
0.7	70	2	1.7	0.3	15
0.7	100	2	1.3	0.3	35
0.7	150	2	0.9	1.1	55



% Cadmium removal

D. Effect of Adsorbent dose

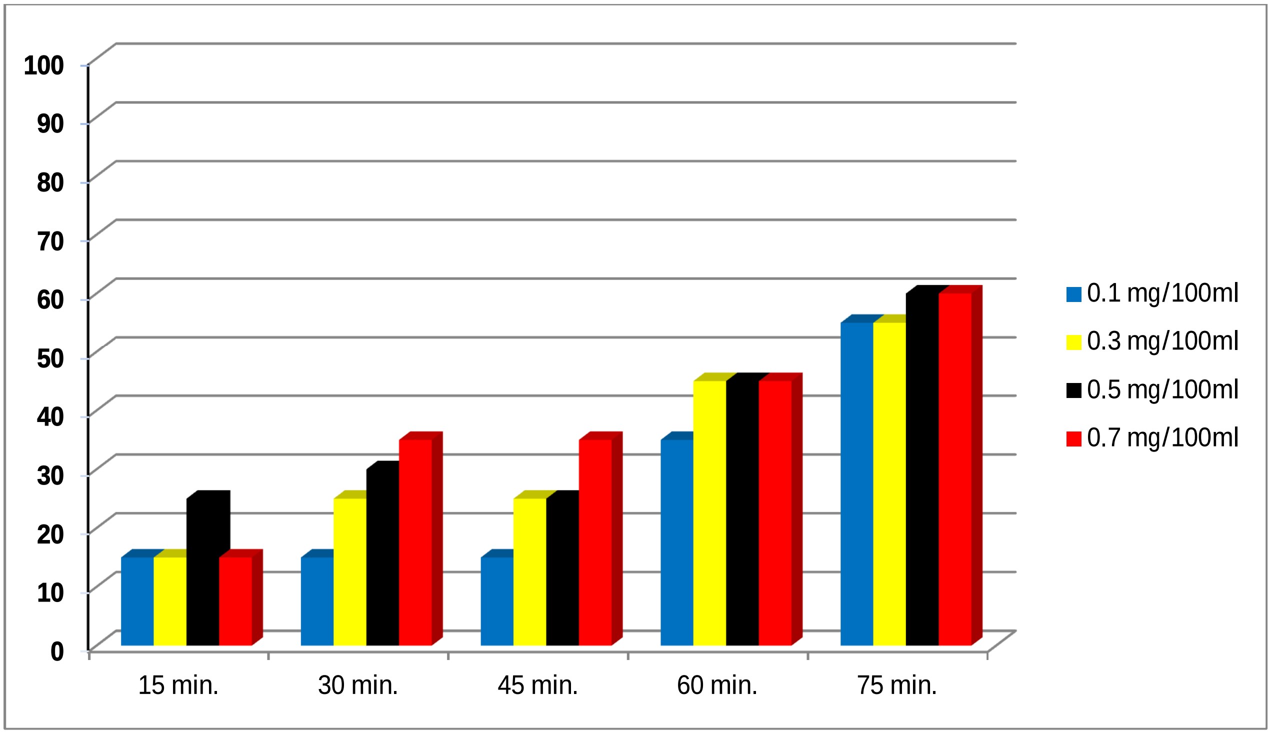
The effect of the adsorbent dose on the removal of cadmium was studied by varying the dose from 0.1g/100ml to 0.7g/100ml. The results are presented, where it can be seen that maximum removal of about 60% is found at an adsorbent dose of 0.5 g/100ml and thereafter the percent removal became equal and more or less constant.

Dose(g/100ml)	Contact time (min)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.1	15	2	1.7	0.3	15
0.1	30	2	1.7	0.3	15
0.1	45	2	1.7	0.3	15
0.1	60	2	1.3	0.7	35
0.1	75	2	0.9	1.1	55

Dose(g/100ml)	Contact time (min)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.3	15	2	1.7	0.3	15
0.3	30	2	1.5	0.5	25
0.3	45	2	1.5	0.5	25
0.3	60	2	1.1	0.9	45
0.3	75	2	0.9	1.1	55

Dose(g/100ml)	Contact time (min)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.5	15	2	1.5	0.5	25
0.5	30	2	1.4	0.6	30
0.5	45	2	1.5	0.5	25
0.5	60	2	1.1	0.9	45
0.5	75	2	0.8	1.2	60

Dose(g/100ml)	Contact time (min)	Initial cadmium (mg/l)	Final cadmium(mg/l)	Reduction in cadmium (mg/l)	% removal efficiency
0.7	15	2	1.7	0.3	15
0.7	30	2	1.3	0.7	35
0.7	45	2	1.3	0.7	35
0.7	60	2	1.1	0.9	45
0.7	75	2	0.8	1.2	60



% Cadmium Removal

V. CONCLUSION

Based on the results of this study, it can be concluded that sacchurum officinarum (sugarcane bagasse [SB]) have good performance to adsorb cadmium from an aqueous solution especially for high concentration of cadmium and had given an excellent results. The biosorbent was successful in removal of cadmium 2+ ions from aqueous solution of 0.5mg/l cadmium concentration with about 65%

efficiency at 9 pH in room temperature. It was also observed that the adsorption was pH dependent

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